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YIELD TABLES FOR MANAGED EVEN-AGED STANDS OF SPRUCE-FIR IN THE CENTRAL ROCKY MOUNTAINS

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Abstract

Presents procedures for deriving yield tables for managed stands of spruce-fir from data obtained on temporary plots, and the computer programs developed by Myers (1971). Oxford: 566 (083.5) 6

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Authors' Preface

The procedures for computing yield tables for managed even-aged stands of spruce-fir presented in this Paper were adapted from the field and computer procedures for managed stand yield tables developed by Myers (1971). We replaced the species-specific statements for ponderosa pine with functions applicable to spruce-fir, and made a few minor changes in the way the program operates. Much of Myers' original text is repeated here so that readers will not have to refer to two publications.

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**Yield Tables for Managed Even-Aged Stands
of Spruce-Fir in the Central Rocky Mountains** ^[Computer program]

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Yield Tables for Managed Even-Aged Stands of Spruce-Fir in the Central Rocky Mountains

Robert R. Alexander, Wayne D. Shepperd,
and Carleton B. Edminster

Timber management in the Engelmann spruce (*Picea engelmannii*)-subalpine fir (*Abies lasiocarpa*) type in the central and southern Rocky Mountains is in a period of transition to more intensive and varied management practices. Large areas of old-growth forests are rapidly being converted to stands that must be managed from the regeneration period to harvesting. Yield tables that predict probable yields of wood that will result from specified combinations of site quality, frequency and intensity of thinning, and utilization standards provide goals toward which conversion can be directed. They also provide part of the information needed to determine the influence of timber management practices on other forest resources (Myers 1971). Land managers can examine alternatives and make decisions through computerized evaluation (Program TEVAP2) of forestry activities, a procedure that uses yield-table computation in a set of mathematical operations (Myers 1974).

Procedures for the computation of yield tables for managed even-aged stands of spruce-fir presented in this Paper were adapted from the field and computer procedures for managed stand yield tables (Program PONYLD) developed by Myers (1971). Included are (1) identification of the field measurements that provide the basic data needed to produce the yield tables, (2) the relationships that replace the species-specific statements in Myers' Program PONYLD, (3) the computer program (SPRYLD) written in FORTRAN IV that computes and prints yield tables for spruce-fir, and (4) an example of what program SPRYLD can produce. The computer program SPRYLD has the capacity of producing a series of yield tables which show how projected outcomes will vary in response to changes in cultural treatments and/or variations in original stand and site

conditions. Large numbers of tables, each based on a specific set of alternatives, can be computed and printed for a few cents each. They provide the manager with the opportunity to examine the probable results of his operations, make necessary changes in management goals, and study the effect of these changes before money is spent on them (Myers 1971).

General Description of Methods

The nine items of information (working tools) described later are species-specific statements in Myers' (1971) computer program. All but the first item, the desired residual stand after each cutting which is based on available information from thinned stands, were replaced to compute yield tables for even-aged managed stands of spruce-fir. Data for these eight items of information were based on temporary growth prediction plots measured in detail. Tree volume equations (Myers and Edminster 1972) and site index curves (Alexander 1967) applicable to spruce-fir stands in the central Rocky Mountains were used in the analyses of data described in the following sections.

There are no thinned stands of spruce-fir in the central Rocky Mountains, and partially cut stands were unsuitable for sampling; therefore, the growth prediction plots were placed in 69 undisturbed even-aged stands throughout the spruce-fir type in Colorado and Wyoming. These plots, chosen to approximate what a managed stand might look like, conformed to the usual requirements as to uniformity of site quality, range in tree sizes, and stand density across the plot. The trees were also free of diseases or insect infestations that would affect growth. The plots covered a range of site quality (SI 40 to

110) and stand density (30 to 1,600 stems per acre). Age classes varied from 20 to 160 years.

Measurements made on each growth prediction plot included the following:

1. Plot area.
2. Heights and ages of 6 to 10 dominant trees suitable for site index determination (Alexander 1967).
3. Diameter at breast height (d.b.h.) of each tree to the nearest 0.1 inch.
4. Total height of each tree to the nearest 1.0 foot, or a sufficient sample in each diameter class to construct a height/diameter curve where a large number of trees were measured. Heights of all dominants and codominants were measured except where tops were dead, defective, or deformed.
5. Crown class of each tree.
6. Total ages of a sample of dominant and codominant trees to validate even-age status of the main stand.
7. Radial wood growth during the past 10 years from increment borings at breast height along an average radius.
8. D.b.h. outside bark of all trees that appeared to have died during the last 10 years.
9. On 12 plots, a number of cut or leave codes for each tree based on trial marking to simulate several intensities of thinning. This information was used to provide some of the input needed to determine diameter and height increases due to thinning, stand volumes, and volume conversion factors. Additional simulated data were generated using Program SPRCHK, a modification of Program PONCHK (Myers 1971). The 12 plots were also used to verify the SPRCHK output.

Plot and tree data computed initially from the field measurements included:

1. Site index (Alexander 1967).
2. A height-diameter curve for each plot to provide a height for each tree for which actual height was not measured.

Measured and computed items that describe the present stand were used to compute the following values for each plot:

1. Number of trees per acre.
2. Number of dominants and codominants per acre.
3. Basal area per acre.
4. Average d.b.h., computed as the tree of average basal area.
5. Average height of dominant and codominant trees.

6. Average height of all trees.

7. Average main stand age.

8. Total cubic feet from ground to tip for all trees, per acre.

9. Merchantable cubic feet to a 4-inch top in trees 5 inches d.b.h. and larger, per acre.

10. Board feet (Scribner Rule) to a 6-inch top in trees 8 inches d.b.h. and larger, per acre.

All except item 7 were generated as part of the output of Program SPRCHK.

Diameters of live trees, diameters of the tallied dead trees, and present stand age on each plot provide the following items that described the stands 10 years ago at the beginning of the prediction period.

1. Number of trees, per acre.
2. Basal area, per acre.
3. Past d.b.h. of each tree from present d.b.h., radial wood growth, and periodic bark growth (Myers and Alexander 1972).
4. Average stand diameter (tree of average basal area).
5. Average main stand age (present main stand age minus 10 years).

Development of Items to Replace Species-Specific Statements and Other Modifications Needed to Adapt Myers' (1971) Program PONYLD to SPRYLD

After plot measurements were obtained and summarized, the items described below were computed as one or more relationships to convert the species-specific statements in Program PONYLD to spruce-fir. Most of the nine items that appear as FORTRAN statements in Program SPRYLD and its associated subroutines SPRCUT and SPRVOL were obtained by regression analysis of plot values described above.

1. Stocking After Cutting

Stand density to be left after each cutting is expressed as the relationship between basal area and average stand diameter. Data on spruce-fir from thinning studies or temporary plots were not available to construct a graph of desired basal area over stand diameter for local average diameter. Data for this item were taken directly from Myers' (1971) Program PONYLD. When sufficient

information for spruce-fir becomes available, this item will be examined and necessary adjustments made.

The following, taken from Myers (1971), is repeated here for continuity.

"In table 1, basal area increases with diameter until 10.0 inches diameter is reached, and remains constant thereafter. The designation 'growing stock level 80' indicates that basal area is 80.0 ft² when diameter is 10.0 inches or larger, regardless of what basal area may be at lower average diameters.

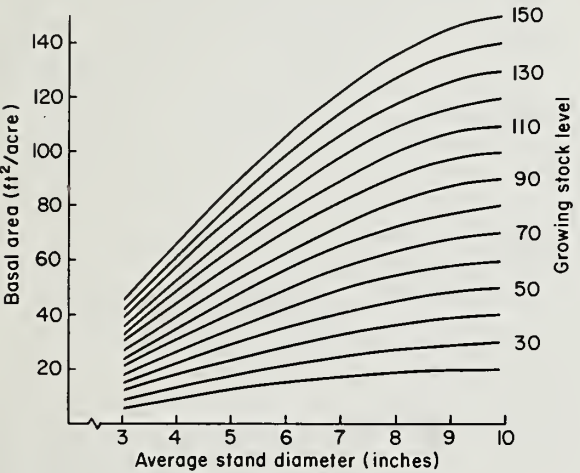


Figure 1. — Basal area after thinning in relation to average stand diameter for standard levels of growing stock (from Myers 1971).

"Desired stand density will vary with the objectives of management, and a family of basal area-diameter relationships is needed (fig. 1). The original single curve or function of basal area on diameter is treated as a guide curve from which other curves can be produced. Basal areas for any growing stock level can be computed by multiplying the guiding values for level 80 in table 1 by the ratio level/80."

The level designations that are the variables THIN, REST, and DSTY in SPRYLD are the same as appear in PONYLD.

The curves of figure 1 define growing stock goals for many possible management objectives. Any desired form of the guide curve may be used if the appropriate

Table 1.--Basal areas after intermediate cutting in relation to average stand diameter growing stock level 80 (from Myers 1971)

Average stand d.b.h. after cutting (Inches)	Basal area per acre	Average stand d.b.h. after cutting (Inches)	Basal area per acre
	ft ²		ft ²
2.0	12.1	6.0	56.6
2.1	13.2	6.1	57.6
2.2	14.4	6.2	58.5
2.3	15.5	6.3	59.4
2.4	16.7	6.4	60.3
2.5	17.9	6.5	61.2
2.6	19.0	6.6	62.1
2.7	20.2	6.7	62.9
2.8	21.3	6.8	63.8
2.9	22.5	6.9	64.6
3.0	23.7	7.0	65.4
3.1	24.8	7.1	66.2
3.2	26.0	7.2	67.0
3.3	27.1	7.3	67.7
3.4	28.3	7.4	68.5
3.5	29.5	7.5	69.2
3.6	30.6	7.6	69.9
3.7	31.8	7.7	70.6
3.8	32.9	7.8	71.2
3.9	34.1	7.9	71.9
4.0	35.2	8.0	72.5
4.1	36.4	8.1	73.1
4.2	37.6	8.2	73.7
4.3	38.7	8.3	74.3
4.4	39.9	8.4	74.8
4.5	41.0	8.5	75.3
4.6	42.2	8.6	75.8
4.7	43.4	8.7	76.3
4.8	44.5	8.8	76.7
4.9	45.7	8.9	77.1
5.0	46.8	9.0	77.5
5.1	47.8	9.1	77.9
5.2	48.8	9.2	78.2
5.3	49.8	9.3	78.5
5.4	50.8	9.4	78.8
5.5	51.8	9.5	79.1
5.6	52.8	9.6	79.3
5.7	53.8	9.7	79.5
5.8	54.7	9.8	79.7
5.9	55.7	9.9	79.8
		10.0+	80.0

statements of subroutine SPRCUT are modified properly.

Relationships shown in table 1 appear as functions for level 80 in program SPRYLD.

Basal areas computed from these functions are multiplied by terms that include the desired growing stock level (THIN) to obtain values for other growing stock levels. Variables for which FORTRAN statements were taken from PONYLD and their use, were:

- "a. DBHP — to find a d.b.h. less than 10.0 inches when basal area is known. Three equations for DBHP are used to simplify representation of the nonlinear relationship between d.b.h. and basal area.
- b. BREAK and BUST — to compute values of basal area that are the upper limits of applicability of the first two equations for DBHP.
- c. SQFT — to find basal area when d.b.h. is known. Two equations represent the nonlinear relationship for d.b.h. less than 10.0 inches."

2. Description of Unthinned, Young Stands

Values in the first line of each yield table describe stand conditions just prior to initial thinning. They are entered directly from data cards or are computed from the data. Users of SPRYLD must, therefore, be able to describe the stands that do or should exist at time of initial thinning. In a yield table for managed stands, the stand density and related average diameter given in the first line result when stand regeneration and subsequent growth and mortality progress as planned.

Only a few unthinned young spruce-fir stands were found that represented possible regeneration goals for various management objectives. Furthermore, no usable data were available from yield studies made elsewhere. It was not possible, therefore, to determine average diameter for each site class for various combinations of age and number of trees per acre. Instead, an average diameter in relation to number of trees per acre was determined for an average site index at age 30 years, the youngest age appearing in the yield tables. It was then necessary to make a judgment decision as to the average diameters and number of trees that appeared reasonable for managed stands at the time of first thinning for each site class. These values range from 800 stems per acre with an average diameter of 4.7 inches for site index classes 100 and greater to 950 stems per acre

with an average diameter of 4.4 inches for site index classes 40 and 50. As more young stands with reasonable spacing reach 30 years of age, additional data will become available to evaluate this first approximation, and make necessary adjustments.

3. Diameter Increase from Growth

Regression analysis of data from growth prediction plots provided an equation for predicting future average stand diameter of spruce-fir. Present average stand diameter is estimated from past average stand diameter, site index, and past basal area per acre. The following equation for a 10-year prediction period appears in SPRYLD as the FORTRAN statement for DBHO:

$$\text{DBHO} = 1.62917 + 1.03371 (\text{DBHT}) \\ + 0.01304 (\text{SITE}) - 0.90669 (\log_{10} \text{BAST})$$

$$S_{yx} = 0.2469 \quad R^2 = 0.9948$$

where DBHO = present average stand diameter.
 DBHT = past average stand diameter.
 SITE = site index.
 BAST = past basal area per acre.

4. Diameter Increase from Thinning

The change in average stand diameter resulting from intermediate cuttings was estimated from data obtained by trial marking of growth prediction plots, and the supplemental procedure developed by Myers (1971) and generated by Program SPRCHK. This later procedure provided simulated data on combinations of initial stand diameters, stocking level, and stand density not available from the trial markings.

In subroutine SPRCUT, diameter after thinning is estimated from diameter before thinning and the percentage of trees to be retained. Regression analysis of data from simulated thinnings provides two functions — DBHE and PDBHE — that represent the same variable, diameter after thinning.

DBHE is computed directly in subroutine SPRCUT from the following equation if at least 50 percent of the trees are retained:

$$DBHE = 0.02666 + 1.30655 (DBHO) - 0.00306 (DBHO \times PRET)$$

$$S_{yx} = 0.1413, R^2 = 0.9985$$

where DBHE = average diameter after thinning.

DBHO = average stand diameter before thinning.

PRET = percentage of trees retained after thinning.

With fewer trees retained, the relationship is nonlinear, so PDBHE is computed in subroutine SPRCUT from the following equation and its antilogarithm becomes DBHE:

$$PDBHE = 0.33206 + 0.98346 (\log_{10} DBHO) - 0.14170 (\log_{10} PRET)$$

$$S_{yx} = 0.0187, R^2 = 0.9898$$

5. Heights of Dominants and Codominants

Average heights of dominant and codominant trees were computed from data from the growth prediction plots and from Alexander's (1967) site index curves adjusted from dominant height to dominant and codominant height (table 2). Regression analysis provided two equations that appear as statements for HTSO in SPRYLD, for estimating height for various combinations of age and site index:

The equations are shown below:

$$\begin{aligned} HTSO (AGEO < 100) = & -13.71751 + \\ & 0.15087 (SITE) + 0.00126 (AGEO^2) + \\ & 0.01371 (AGEO \times SITE) \\ & - 0.00006 (AGEO^2 \times SITE) \end{aligned}$$

$$S_{yx} = 2.0074, R^2 = 0.9920$$

$$\log_{10} HTSO (AGEO \geq 100) = 0.91859$$

$$- \frac{100.43601}{AGEO} + 0.62318 (\log_{10} SITE)$$

$$+ 40.08154 \frac{\log_{10} SITE}{AGEO}$$

Table 2.--Average height (feet) of dominant and codominant trees at various ages and site indexes for Engelmann spruce (as computed by statements for HTSO)

Main stand age (years)	Site index (Based on dominant trees)						
	40	50	60	70	80	90	100
20	3	7	11	15	19	23	27
30	8	13	18	23	28	33	38
40	12	18	25	31	37	43	49
50	17	24	31	37	44	51	58
60	21	29	36	44	51	59	67
70	25	33	41	50	58	66	74
80	29	37	46	55	63	72	81
90	33	41	50	60	68	77	87
100	36	45	54	64	73	82	92
110	39	48	58	67	77	86	96
120	41	51	61	70	80	89	99
130	43	54	63	73	83	92	102
140	45	56	66	76	86	95	105
150	47	58	68	78	88	98	107
160	49	60	70	80	90	100	109
170	51	61	72	82	92	101	111
180	53	63	73	83	93	103	113

$$S_{yx} = 0.0101, R^2 = 0.9938$$

where HTSO = average height of dominant and codominant trees before thinning.

SITE = site index.

AGEO = main stand age.

6. Height Increase from Thinning

Changes in the average height of dominant and codominant trees due to intermediate cuttings were estimated from data provided by trial markings of growth prediction plots, and simulated thinnings generated by Program SPRCHK for various additional combinations of stocking level, initial stand diameter, and initial stand density. In SPRYLD, the variable ADDHT is the computed amount of change estimated from the percentage of trees retained (PRET) by the equation below:

$$ADDHT = -1.81392 + 17.77922 \sqrt{\frac{1}{PRET}}$$

$$S_{yx} = 0.0864, R^2 = 0.9958$$

At each cutting, the current value of ADDHT is added to height before thinning, HTSO, to obtain height after thinning, HTST. It is also added to a cumulative sum of changes, HTCUM, so that computed heights before thinning will show the effects of past treatments as well as of age. Values for ADDHT are small because changes in height are for dominant and codominant trees only.

7. Noncatastrophic Mortality

Mortality in unthinned stands is usually more important than in thinned stands. Since the only data available were from growth prediction plots, and they were located in unthinned stands with spacings that appeared desirable for managed stands, estimates of mortality in managed stands are only approximate. Furthermore, we did not compute a prediction equation for mortality for spruce-fir stands with an average diameter of 10.0 inches or larger because of the wide variability in mortality in those stands.

The prediction equation in SPRYLD for stands with an average diameter of less than 10.0 inches, shown below for the percentage of mortality expressed as a decimal (DIED), contains average stand diameter and basal area at the beginning of the period as independent variables:

$$\text{DIED} = -0.0003967 + 0.0000382 (\text{DBHT} \times \text{BAST})$$

$$S_{yx} = 0.0055, \quad R^2 = 0.9677$$

where DIED = percentage of trees that have died during measurement period (10 years).
DBHT = average stand diameter at the beginning of the measurement period.
BAST = basal area per acre at the beginning of the measurement period.

8. Stand Volume Equation

Plot tallies of tree diameters and heights from growth prediction plots, the result of

simulated thinnings, and trial markings were converted to total cubic foot, merchantable cubic foot, and board foot volumes per acre with appropriate tree volume equations (Myers and Edminster 1972). In subroutine SPRVOL, only total cubic foot volumes per acre are computed directly, and therefore are the only unit of measure for which a stand volume equation is needed.

Stand volume equations appear as statements to compute CUFT in subroutine SPRVOL. Two statements were used because the relationship was not linear over the range of D^2H that can appear in the yield tables:

$$\text{CUFT} (D^2H < 22,500) = (0.34430 - 0.00524\text{BA} + 0.0023575D^2H) \times N$$

$$S_{yx} = 0.4982, \quad R^2 = 0.9986$$

$$\text{CUFT} (D^2H \geq 22,500) = (7.60196 - 0.01052\text{BA} + 0.0020103D^2H) \times N$$

$$S_{yx} = 1.9210, \quad R^2 = 0.9940$$

where CUFT = total cubic foot volume per acre.

D = average stand diameter.

BA = basal area per acre.

H = average height of dominant and codominant trees.

N = number of trees per acre.

The standard errors of estimate quoted above result from the prediction of cubic foot volume of a tree of average d.b.h. and height, before multiplying by number of trees per acre.

9. Volume Conversion Factors

Subroutine SPRVOL computes volumes in merchantable cubic feet and board feet from total cubic volume per acre and appropriate conversion factors. Data from growth prediction plots, trial markings, and simulated thinnings that produced the stand volume equations also provided conversion factors. The quantity of each unit per total cubic foot was determined separately for each data point. A stand diameter of 5.0 inches and top diameter of 4.0 inches for merchantable cubic feet, and a stand diameter of 8.0 inches and top diameter of 6.0 inches for board feet,

were selected as appropriate minimums. Regression analysis provided the function to compute the conversion from total cubic volume to merchantable cubic volume and board foot volumes that appear as statements FCTR and PROD in SPRVOL. FCTR can be estimated by the following equation from average stand diameter:

$$\begin{aligned} \text{FCTR} &= 0.82375 + \frac{3.45569}{D} \\ &+ 0.00013(D^2) - \frac{28.86783}{D_2} \\ S_{yx} &= 0.0273, \quad R^2 = 0.9572 \end{aligned}$$

Estimates of PROD for spruce-fir can be improved if basal area is included with diameter in the equations. Two equations shown below appear in SPRVOL so the relationships can be expressed in simpler terms over a wide range of diameters:

$$\begin{aligned} \text{PROD (D < 16.5 inches)} &= 4.59159 - \\ &\frac{214.06370}{D^2} + 0.39782 (\log_{10} \text{ BA}) \\ S_{yx} &= 0.1567, \quad R^2 = 0.9561 \end{aligned}$$

$$\begin{aligned} \text{PROD (D} \geq 16.5 \text{ inches)} &= 8.59422 - \\ &\frac{19.54507}{\sqrt{D}} + 0.44432 (\log_{10} \text{ BA}) \\ S_{yx} &= 0.1191, \quad R^2 = 0.8575 \end{aligned}$$

Description of Program SPRYLD

Program SPRYLD consists of a main program and two subroutine subprograms written in standard FORTRAN IV. The main program reads the data cards, performs most computations, and writes the yield tables. Subroutine SPRCUT determines the new average stand diameter and percentage of trees retained after cutting to the specified growing stock level. Subroutine SPRVOL computes volumes in total cubic feet per acre, and factors to convert these volumes to other units. Operations performed by each routine are indicated by comment statements in the source listing (Appendix 1).

As mentioned earlier, program SPRYLD computes and prints sets of yield tables. The

variable NTSTS, read from data card type 1, controls the number of sets of tables. The number of yield tables within a set is controlled by variable MIX, read from data card type 3. The first yield table of each set is computed from initial conditions and controls on operations specified on data cards type 3, 4, and 5. Subsequent yield tables within a set are computed from the same conditions and controls, with the exception of the growing stock level for intermediate cuts after initial thinning. This growing stock level is increased by the value of DSTINC (read from data card type 3) over the level of the previous yield table. Operations performed for each yield table are:

1. Computation of basal area, height, and volumes just prior to initial thinning.
2. Partial cutting to the growing stock level specified for initial thinning or subsequent cutting. Cutting will not be simulated if the stand is already below the growing stock level specified.
3. Computation of post-cutting density, basal area, height, and volumes.
4. Printing of table headings once for each yield table and printing of values appropriate for the stand age.
5. Projection of diameter, height, and stand density for one or more periods until the next intermediate cut is scheduled. Stand volumes and other values are computed and printed at ages when no cutting is scheduled.
6. Repetition of steps 2 to 5 until stand age at time of initial regeneration cutting is reached.
7. Redefinition of the growing stock to be left after cutting and the interval between regeneration cuttings if shelterwood cuttings are specified. Table computations will be terminated if clearcutting is specified.
8. Repetition of steps 2 to 7 to accomplish regeneration cuts until the age of the final cut is reached.
9. Printing of totals for volumes removed. Volumes less than COMCU or COMBF (read from data card type 2) will not be included in the totals so that total commercial yields may be compared, if desired. Actual totals may be obtained by entering values of 1.0 for COMCU and COMBF on data card type 2.

Subroutine SPRCUT computes average stand diameter after cutting from diameter before cutting and the percentage of trees

retained. The percentage of trees retained is needed as an independent variable, but is itself an unknown. Successive percentages of trees retained are tested until d.b.h. after thinning, number of trees retained, and residual basal area agree with the diameter and basal area combination specified by the growing stock level of the cut. These combinations are shown in table 1 for growing stock level 80.0.

Subroutine SPRVOL computes total cubic feet per acre and factors to convert this volume to other units. Conversions to merchantable cubic feet and to board feet are shown in Appendix 1. Utilization standards for these units are given in subsection 9 of the previous section and in the comment statements of SPRVOL. Conversions to other units or utilization standards may supplement or replace those already in SPRVOL.

Program SPRYLD should run with little or no modification on any computer that accepts FORTRAN IV, has a minimum of 32K words of storage, and has two input/output devices (unit 5 for program and data deck input and unit 6 for printed output). Changes to adapt the program to other utilization standards and for additional computations are described by Myers (1971) in his section headed Modifications of PONYLD, and are not repeated here.

Description of the Data Deck for Program SPRYLD

The data deck for program SPRYLD consists of five types of data cards. These cards are numbered by their order of appearance in the data deck except that cards type 3, 4, and 5 may be repeated in sets as specified by variable NTSTS from card type 1. The first two cards of the data deck (types 1 and 2) enter values which do not change during a computer run. Cards type 3, 4, and 5 enter values used in the computation of a set of yield tables which may change between sets of tables. The contents of each data card are described in the following tabulation of the order and contents of the data deck.

An Application of SPRYLD

The problem described below demonstrates the computations made by

SPRYLD and the printed results obtained. It illustrates some of the questions that may be asked and the information that will be provided. The example also serves as a test problem for use in adapting the source program to locally available computing facilities.

A forest manager wishes to determine the intensity of thinning that will maximize volume production in board feet in stands of site index 80 (SITE). Length of the cutting cycle (JCYCL) has not been standardized, but will be 30 years for this test. He also wants to compare yields from two-cut and three-cut shelterwood, both with the final removal cut scheduled for stand age 150 years (REGN(2) for two-cut shelterwood, REGN(3) for three-cut shelterwood) and considering the current crop only. Alternatives calling for more than one precommercial thinning are unacceptable. Minimum commercial volumes per acre are 400 cubic feet (COMCU) and 2000 board feet (COMBF). The manager expects that his procedure for regeneration cuts will result in a new stand that contains 850 trees per acre (DENO) by age 30 (AGEO), with an average diameter of 4.6 inches (DBHO). (The data deck consisting of 32 cards is shown in fig. 2.)

COLUMN NUMBERS									
111111111122222222223333333333444444445									
12345678901234567890123456789012345678901234567890									
CARD TYPE	1	2	3	4	5	6	80	10	
1						400		2000	
2						30	3	20	
3						30		45	850
4						120		80	150
5									80
6						30	3	20	
7						30		45	850
8						120		80	150
9									80
10						30	3	20	
11						30		45	850
12						120		80	150
13									80
14						30	3	20	
15						30		45	850
16						120		80	150
17									80
18						30	3	20	
19						30		45	850
20						120		80	150
21									80
22						30	3	20	
23						30		45	850
24						120		80	150
25									80
26						30	3	20	
27						30		45	850
28						120		80	150
29									80
30						30	3	20	
31						30		45	850
32						120		80	150

Figure 2. — Data deck for test problem.

Yield tables produced by SPRYLD, a few of which are reproduced in Appendix 2, can assist in decision-making in many ways. Money yields and rates earned can be com-

Order and Contents of the Data Deck for Program SPRYLD

Card type	Number of cards	Variable name	Columns	Format	Description of variable
1	1	NTSTS	1-4	I4	Number of tests or sets of yield tables to be produced (greater than or equal to 1). Base level of set of growing stock levels (equal to 80.0 for the listing in Appendix 1).
		GIDE	5-8	F4.0	
		RINT	9-12	F4.0	
2	1	COMCU	1-8	F8.3	Minimum cut in merchantable cubic feet per acre to be included in total yields (greater than or equal to 1.0).
		COMBF	9-16	F8.3	Minimum cut in board feet per acre to be included in total yields (greater than or equal to 1.0).
3	1 per test	JCYCL	1-4	I4	Interval between intermediate cuts. A multiple of RINT.
		MIX	5-8	I4	Number of stocking levels for intermediate cuts to be examined in one test. Equivalent to number of yield tables produced per test (greater than or equal to 1).
		DSTINC	9-16	F8.3	Amount growing stock level (for intermediate cuts after initial thinning) will be increased over level of previous yield table in a test if MIX is greater than 1. Leave blank if MIX equals 1.
4	1 per test	AGEO	1-8	F8.3	Initial age in years to be shown in a yield table. Stand age when first thinning occurs (greater than 0.0).
		DBHO	9-16	F8.3	Average stand d.b.h. in inches just prior to initial thinning at stand age AGEO (greater than 0.0).
		DENO	17-24	F8.3	Number of trees per acre just prior to initial thinning at stand age AGEO (greater than 0.0).
		DSTY	25-32	F8.3	Lowest growing stock level for intermediate cuts after initial thinning in a test. Level will increase by DSTINC on the second and subsequent yield tables in a test if MIX is greater than 1. Value of DSTY must be greater than 0.0.
		SITE	33-40	F8.3	Site index for the stand (greater than 0.0).
		THIN	41-48	F8.3	Growing stock level for initial thinning at age AGEO (greater than 0.0).
5	1 per test	REGN(1) ¹	1-8	F8.3	Stand age at which first regeneration cut will occur. Must be greater than 0.0 as REGN(1) is rotation age for clear-cutting.
		VLLV(1)	9-16	F8.3	Percentage, as a decimal, of growing stock level for intermediate cuts to be left at age REGN(1). Leave this and next 3 variables blank for clearcutting.

Order and Contents of the Data Deck for Program SPRYLD (cont'd)

Card type	Number of cards	Variable name	Columns	Format	Description of variable
		REGN(2) ¹	17-24	F8.3	Stand age at which second regeneration cut, if any, will occur. Final cut of 2-cut shelterwood or second cut of 3-cut shelterwood.
		VLLV(2)	25-32	F8.3	Percentage, as a decimal, of growing stock level left after first regeneration cut to be left at age REGN(2). Leave this and next variable blank for 2-cut shelterwood.
		REGN(3) ¹	33-40	F8.3	Stand age at which third regeneration cut, if any, will occur. Final cut of 3-cut shelterwood.

¹Values for ages for regeneration cuts must equal the value of AGE0 plus a multiple of the value of RINT.

puted by applying thinning costs and stumpage values to the volumes given in the tables. Stand ages at culmination of mean annual increment, and rates earned assist in the selection of rotations.

For the situation described above, yields and numbers of precommercial thinnings are of greatest immediate interest. These items are summarized in tables 3 and 4 for the 18 yield tables produced. Combinations of high initial and intermediate subsequent growing stock levels produce the greatest volumes with one precommercial thinning. Additional comparisons should be made to include such

factors as probable thinning costs, cubic yields from thinnings not commercial for board feet, and the average size of tree produced. As expected, the current crop produces more board feet in 150 years if cut by two-cut shelterwood than if by three-cut shelterwood. The latter treatment may, however, get the next crop off to an earlier start.

Modifications of SPRYLD

SPRYLD can be modified to study actual stands, especially to determine if treatment in unthinned stands is justified, and to add other measures and variability as described for PONYLD by Myers (1971).

Table 3.--Yields in board feet, including commercial thinnings, of the 18 combinations of initial and subsequent growing stock levels¹

Initial growing stock level	Subsequent growing stock level		
	80	100	120
- - - - mbd ft - - - -			
<u>Two-cut Shelterwood</u>			
80	40.9	46.3	53.4
100	41.8	47.5	52.8
120	42.1	47.9	52.2
<u>Three-cut Shelterwood</u>			
80	37.2	42.2	48.2
100	38.4	43.6	48.2
120	39.0	44.5	48.0

¹See text p. 3 for description of growing stock levels.

Table 4.--Number of precommercial thinnings if each of the 18 combinations of initial and subsequent growing stock levels¹ is established as specified by the data deck. (Both types of cutting gave the same results)

Initial growing stock level	Subsequent growing stock level		
	80	100	120
80	1	2	2
100	1	1	2
120	1	1	2

¹See text p. 3 for description of growing stock levels.

Description of Program SPRCHK

Program SPRCHK — used to calculate volumes, volume conversion factors, and diameters and heights for different combinations of stand variables not available from growth prediction plots — is the same as Myers (1971) Program PONCHK, except that the equations used to compute volumes are for spruce (Myers and Edminster 1972).

Modifications Needed to Use Spruce-Fir in Myers' (1974) Program TEVAP2

Subroutine WORKGP in Myers (1974) TEVAP2 permits the program to be used with other species. To use spruce-fir, replace the dummy continue statement number 4 with a CALL statement that will call subroutine ESSF, the species-specific statements for spruce-fir to be used with TEVAP2. SPNUM (I) equal to 4 will then designate subroutine ESSF. The subroutine organization is shown in Appendix 3.

Basic information used in ESSF has been described earlier, with the exception of one equation (ADD) which is included to estimate merchantable cubic volume obtained as a byproduct of saw-log cuts. ADD is computed from stand diameter as follows:

$$ADD = 1.54375 + \frac{11.43324}{D}$$

$$S_{yx} = 0.1168, \quad R^2 = 0.8517$$

where ADD = cubic foot volume of saw
 logs (hundreds of cubic
 feet per m board feet).
 D = average stand diameter.

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Appendix I: Listing of Program SPRYLD

```

PROGRAM SPRYLD
1(INPUT,OUTPUT,TAPE5=INPUT,TAPE6=OUTPUT)

C
C TO COMPUTE AND PRINT YIELD TABLES FOR MANAGED EVEN-AGED STANDS OF
C ENGELMANN SPRUCE AND SUBALPINE FIR.
C
C DEFINITIONS OF VARIABLES.
C
ADDHT = INCREASE OR DECREASE IN AVERAGE STAND HEIGHT BY THINNING.
C
AGED = INITIAL AGE IN YIELD TABLE.
C
BASC = BASAL AREA CUT PER ACRE.
C
BASD = BASAL AREA PER ACRE BEFORE THINNING.
C
BAST = BASAL AREA PER ACRE AFTER THINNING.
C
BDFC = BOARD FEET CUT PER ACRE.
C
BDFD = BOARD FEET PER ACRE BEFORE THINNING.
C
BDFT = BOARD FEET PER ACRE AFTER THINNING.
C
CFMC = MERCHANTABLE CU. FT. CUT PER ACRE.
C
CFMD = MERCH. CU. FT. PER ACRE BEFORE THINNING.
C
CFMT = MERCH. CU. FT. PER ACRE AFTER THINNING.
C
COMBF = MINIMUM COMMERCIAL CUT, BOARD FEET.
C
COMCU = MINIMUM COMMERCIAL CUT, CU. FT.
C
DBHD = AVERAGE STAND D.B.H. BEFORE THINNING.
C
DBHT = AVERAGE STAND D.B.H. AFTER THINNING.
C
DENC = TREES CUT PER ACRE.
C
DEND = TREES PER ACRE BEFORE THINNING.
C
DENT = TREES PER ACRE AFTER THINNING.
C
DIED = PERCENTAGE, AS A DECIMAL, OF TREES THAT DIE DURING PERIOD
C RINT.
C
OLEV = GROWING STOCK LEVEL FOR INTERMEDIATE CUTS AFTER FIRST.
C
DSTINC = AMOUNT GROWING STOCK LEVEL FOR INTERMEDIATE CUTS WILL BE
C INCREASED OVER LEVEL OF PREVIOUS YIELD TABLE IN A TEST.
C
DSTY = LOWEST VALUE OF OLEV USED IN A TEST.
C
GIDE = BASE FOR GROWING STOCK LEVELS, BD.D IN EXAMPLE SHOWN.
C
HTSD = TREE HEIGHT BEFORE THINNING.
C
HTST = TREE HEIGHT AFTER THINNING.
C
JCYCL = INTERVAL BETWEEN INTERMEDIATE CUTS.
C
JSBD = SUM OF BOARD FEET FROM ALL CUTS WITH YIELD OF COMBF OR
C LARGER.
C
JSMC = SUM OF MERCH. CU. FT. FROM ALL CUTS WITH YIELD OF COMCU OR
C LARGER.
C
JSTF = SUM OF TOTAL CU. FT. FROM ALL CUTS.
C
MIX = NUMBER OF STOCKING LEVELS EXAMINED PER TEST.
C
NTSTS = NUMBER OF TESTS PER BATCH.
C
PRET = PERCENTAGE OF TREES RETAINED AFTER THINNING.
C
REGN(I) = STAND AGE WHEN REGENERATION CUT I OCCURS.
C
RINT = NUMBER OF YEARS FOR WHICH PROJECTION IS MADE.
C
ROTA = FINAL AGE IN YIELD TABLE.
C
SITE = SITE INDEX.
C
THIN = GROWING STOCK LEVEL FOR INITIAL THINNING.
C
TOTC = TOTAL CUBIC FEET CUT PER ACRE.
C
TOTD = TOTAL CUBIC FEET PER ACRE BEFORE THINNING.
C
TOTT = TOTAL CUBIC FEET PER ACRE AFTER THINNING.
C
VLLV(I) = PERCENT OF PREVIOUS OLEV TO BE LEFT AT REGN(I), ENTERED
C AS A DECIMAL.
C
COMMON BA,BAST,CUFT,DBHD,DBHT,DEND,FCTR,HITE,GIDE,PRET,PROD,PEST,S
1TAND,VDM
DIMENSION REGN(3),VAR(10),VLLV(2)

C
DO 1 J=1,10
1 VAR(J) = 0.0

C
C READ NUMBER OF TESTS, BASE OF GROWING STOCK LEVELS, AND LENGTH OF
C PROJECTION PERIOD FROM CARD TYPE ONE.
C
READ (5,5) NTSTS,GIDE,RINT
5 FORMAT (I4,2F4.0)
IF(NTSTS .LE. 0) GO TO 170
IF(GIDE .LE. 0.0) GO TO 170
VAR(5) = RINT

C
C READ MINIMUM COMMERCIAL CUTS FOR COMPUTATION OF COLUMN TOTALS FROM
C CARD TYPE TWO.
C
READ (5,10) COMCU,COMBF
10 FORMAT (I0F8.3)
VAR(8) = COMCU
VAR(9) = COMBF

C
C EXECUTE PROGRAM ONCE FOR EACH SET OF INITIAL VALUES OF INTEREST.
C
DO 160 I=1,NTSTS
JTEM = 0

C
C READ CUTTING INTERVAL AND LEVELS PER TEST FROM CARD TYPE THREE.
C
READ (5,15) JCYCL,MIX,DSTINC
15 FORMAT (2I4,F8.3)
IF(JCYCL .LE. 0 .OR. MIX .LE. 0) GO TO 170
JTEM = JCYCL

C
C READ INITIAL STAND VALUES FROM CARD TYPE FOUR.
C
READ (5,10) AGED,DBHD,DEND,DSTY,SITE,THIN
VAR(1) = AGED
VAR(2) = DBHD
VAR(3) = DEND
VAR(4) = DSTY
VAR(6) = SITE
VAR(7) = THIN

C
C READ SILVICULTURAL CONTROLS FROM CARD TYPE FIVE.
C
READ (5,10) REGN(1),VLLV(1),REGN(2),VLLV(2),REGN(3)
VAR(10) = REGN(1)
DO 20 L=1,10
IF(VAR(L) .LE. 0.0) GO TO 170
20 CONTINUE
OLEV = 0.0
DO 25 NA=1,3
L = 4 - NA
IF(REGN(L) .ED. 0.0) GO TO 25
ROTA = REGN(L)
GO TO 30
25 CONTINUE

C
C PROVIDE FOR SEVERAL GROWING STOCK LEVELS PER TEST.
C
30 DO 160 M=1,MIX
ADDHT = 0.0
BDFD = 0.0
BDFT = 0.0
CFMD = 0.0
CFMT = 0.0
HTCUM = 0.0
JSBD = 0
JSMC = 0
JSTF = 0
TEM = M
OLEV = DSTY + (TEM - 1.0) * DSTINC
BASD = DEND * D.DD54542 * DBHD * DBHD

C
C OBTAIN AVERAGE HEIGHT AND VOLUMES PER ACRE.
C
C-----STATEMENTS FOR HTSD AND IF STATEMENT ARE SPECIES-SPECIFIC.
C
IF(AGED .GE. 100.0) GO TO 35
HTSD = -13.71751 + D.15087 * SITE + D.DD126 * AGED * AGED +
1 D.D1371 * AGED * SITE - D.DDDD6 * AGED * AGED * SITE
GO TO 40
35 HTSD = D.91859 - 100.43601 / AGED + D.62318 * ALOGD(SITE) +
1 40.D8154 * ALOGD(SITE) / AGED
HTSD = 10.0 ** HTSD
40 HITE = HTSD
BA = BASD
STAND = DEND
VDM = DBHD
CALL SPRVOL
TOTD = CUFT
BDFD = CUFT * PROD
CFMD = CUFT * FCTR
REST = THIN

C
C ENTER LOOP FOR REMAINING COMPUTATIONS AND PRINTOUT.
C
DO 130 K=1,100

C
C CHANGE STANDARDS IF A REGENERATION CUT IS DUE.
C
43 IF(AGED .GE. ROTA) GO TO 60
IF(AGED .LT. REGN(1)) GO TO 55
IF(AGED .NE. REGN(1)) GO TO 45
OLEV = OLEV * VLLV(1)
REST = OLEV
JCYCL = REGN(2) - REGN(1) + D.5

GO TO 55
45 OLEV = OLEV * VLLV(2)
REST = OLEV
JCYCL = REGN(3) - REGN(2) + D.5

C
C INCREASE D.B.H. BY THINNING AND COMPUTE PDST-THINNING VALUES.
C
55 CALL SPRCUT
IF(PRET .GE. 100.0) GO TO 56
JDENT = (BAST / (0.0054542 * DBHT * DBHT)) + D.5
DENT = JDENT
BAST = 0.0054542 * DBHT * DBHT * DENT
IF(BAST .LT. BASD) GO TO 58
56 BAST = BASD
HTST = HTSD
DENT = DEND
JDENT = DEND + D.5
DBHT = DBHD
TOTT = TOTD
BDFT = BDFD
CFMT = CFMD
GO TO 60

```

C-----STATEMENT FOR ADDHT IS SPECIES-SPECIFIC.

C
58 ADDHT = - 1.81392 + 17.77922 * SORT(1.0 / PRET)
HTCUM = HTCUM + ADDHT
HTST = HTSO + ADDHT
STANO = DENT
VOM = OBHT
HITE = HTST
BA = BAST
CALL SPRVOL
TOTT = CUFT
BOFT = CUFT * PROD
CFMT = CUFT * FCTR

C CHANGE MODE AND ROUND OFF FOR PRINTING.

C
60 JAGEO = AGE0
JSITE = SITE
JOENO = DENO + 0.5
JHTSO = HTSO + 0.5
JTOTO = (TOTO * 0.1) + 0.5
JTOTO = JTOTO * 10
JBASO = BASO + 0.5
JCFMO = (CFMO * 0.1) + 0.5
JCFMO = JCFMO * 10
JBDOFO = (BDOFO * 0.01) + 0.5
JBDOFO = JBDOFO * 100
JHTST = HTST + 0.5
JTOTT = (TOTT * 0.1) + 0.5
JTOTT = JTOTT * 10
JCFMT = (CFMT * 0.1) + 0.5
JCFMT = JCFMT * 10

IF(JCFMT .GT. JCFMO) JCFMO = JCFMT
JBDOFT = (BDOFT * 0.01) + 0.5
JBDOFT = JBDOFT * 100
IF(JBDOFT .GT. JBDOFO) JBDOFO = JBDOFT
JBAST = BAST + 0.5
JOENC = JOENO - JOENT
JBASC = JBASO - JBAST
JTOTC = JTOTO - JTOTT
JCFMC = JCFMO - JCFMT
IF(JCFMC .LE. 0) JCFMC = 0
JBDFC = JBDOFO - JBDOFT
IF(JBDFC .LE. 0) JBDFC = 0

C SUM PERIODIC CUTS FOR LAST LINE OF YIELD TABLE.

C
IF(AGEO .GE. ROTA) GO TO 70
JSTF = JSTF + JTOTC
CFMC = JCFMC
IF(CFMC .LT. COMCU) GO TO 65
JSMC = JSMC + JCFMC
65 BOFC = JBDFC
IF(BOFC .LT. COMBF) GO TO 70
JSBD = JSBD + JBDFC

C WRITE HEADINGS FOR YIELD TABLE.

70 IF(K .GE. 2) GO TO 92

C-----CHANGE TABLE HEADING FOR OTHER SPECIES.

C
WRITE (6,80) JSITE,JCYCL
80 FORMAT (1H1,/,27X,B2HYIELDS PER ACRE OF MANAGED, EVEN-AGED STANOS
1 OF ENGELMANN SPRUCE AND SUBALPINE FIR/1H0,48X,11HSITE INDEX ,13,1
2H,,14,19H-YEAR CUTTING CYCLE)
WRITE (6,82) THIN,OLEV
82 FORMAT (1H0,41X,26HTHINNING LEVELS= INITIAL -,F6.0,14H, SUBSEQUENT
1 -,F6.0)
WRITE (6,84)
84 FORMAT (1H0,25X,3BHENTIRE STANO BEFORE AND AFTER THINNING,28X,26HP
ERIODIC INTERMEDIATE CUTS)
WRITE (6,86)
86 FORMAT (1H0,9X,5HSTAND,10X,5HBASAL,3X,7HAVERAGE,2X,7HAVERAGE,3X,5H
1TOTAL,3X,9HMERCHANT-,3X,9HSAWNTIMBER,9X,5HBASAL,4X,5HTOTAL,3X,9HMER
2CHANT-,3X,9HSAWNTIMBER)
WRITE (6,88)
88 FORMAT (1H ,10X,3HAGE,4X,5HTREES,3X,4HAREA,4X,6HD.B.H.,3X,6HHEIGHT
1,2X,6HVOLUME,2X,11HABLE VOLUME,4X,6HVOLUME,3X,5HTREES,3X,4HAREA,3X
2,6HVOLUME,2X,11HABLE VOLUME,4X,6HVOLUME)
WRITE (6,90)
90 FORMAT (1H ,8X,7HYEARS),3X,3HNO.,3X,6HSD.FT.,4X,3HIN.,6X,3HFT.,4X
1,6HCU.FT.,5X,6HCU.FT.,6X,6HBD.FT.,4X,3HNO.,3X,6HSD.FT.,2X,6HCU.FT.
2,5X,6HCU.FT.,6X,6HBD.FT.)

C WRITE TABLE ENTRIES OF DIAMETER, VOLUMES, ETC.

C
92 WRITE (6,94) JAGEO,JOENO,JBASO,DBHO,JHTSO,JTOTO,JCFMO,JBDOFO
94 FORMAT (1H0,9X,14,4X,15,2X,14,5X,F5.1,5X,13,4X,15,6X,15,6X,16)
IF(AGEO .GE. ROTA) GO TO 135
WRITE (6,96) JAGEO,JOENT,JBAST,OBHT,JHTST,JTOTT,JCFMT,JBDOFT,JOENC,
1JBASC,JTOTC,JCFMC,JBDFC
96 FORMAT (1H ,9X,14,4X,15,2X,14,5X,F5.1,5X,13,4X,15,6X,15,6X,16,4X,1
15,3X,13,5X,14,6X,14,8X,15)

C COMPUTE VALUES FOR EACH PERIOD. THIN AS SPECIFIED.

C
IRINT = RINT
IK = JCYCL / IRINT
DO 120 L=1,IK
AGEO = AGE0 + RINT
IF(AGEO .GT. ROTA) GO TO 135

C COMPUTE NEW D.B.H. BEFORE THINNING AND ROUND OFF TO 0.1 INCH.

C
C-----STATEMENT FOR DBHO IS SPECIES-SPECIFIC.

C
OBHO = 1.62917 + 1.03371 * OBHT + 0.01304 * SITE - 0.90669 *
1 ALOG10(BAST)
1DBHO = OBHO * 10.0 + 0.5
OBHO = 10BHO
OBHO = OBHO * 0.1

C
C-----STATEMENT FOR DIED IS SPECIES-SPECIFIC. CHANGE 10.0 IN IF
C-----STATEMENT IF OIEO STATEMENT APPLIES TO LARGER TREES.

C
IF(OBHT .GE. 10.0) GO TO 100
OIEO = (-0.03967 + 0.00382 * OBHT * BAST) * 0.01
IF(OIEO .LT. 0.0) OIEO = 0.0
OENO = DENT * (1.0 - OIEO)
MKN = OENO + 0.5
OENO = MKN
GO TO 105
100 OENO = DENT
105 BASO = OENO * (0.0054542 * OBHO * DBHO)

C OBTAIN AVERAGE HEIGHT AND VOLUMES PER ACRE.

C-----STATEMENTS FOR HTSO AND IF STATEMENT ARE SPECIES-SPECIFIC.

C
IF(AGEO .GE. 100.0) GO TO 110
HTSO = -13.71751 + 0.15087 * SITE + 0.00126 * AGE0 * AGE0 +
1 0.001371 * AGE0 * SITE - 0.00006 * AGE0 * AGE0 * SITE
GO TO 115
110 HTSO = 0.91859 - 100.43601 / AGE0 + 0.62318 * ALOG10(SITE) +
1 40.08154 * ALOG10(SITE) / AGE0
HTSO = 10.0 ** HTSO
115 HTSO = HTSO * HTCUM
STANO = OENO
VOM = OBHO
HITE = HTSO
BA = BASO
CALL SPRVOL
TOTO = CUFT
BDOFO = CUFT * PROD
CFMO = CUFT * FCTR

C TEST IF REGENERATION CUT IS DUE.

C
DO 118 KU=1,3
IF(AGEO .EQ. REGN(KU)) GO TO 43
118 CONTINUE

C CHANGE MOOE AND ROUND OFF FOR PRINTING.

C
IF(L .ED. IK) GO TO 125
KOENO = OENO + 0.5
KAGEO = AGE0
KHTSO = HTSO + 0.5
KBASO = BASO + 0.5
KTOTO = (TOTO * 0.1) + 0.5
KTOTO = KTOTO * 10
KCFMO = (CFMO * 0.1) + 0.5
KCFMO = KCFMO * 10
KBOFO = (BDOFO * 0.01) + 0.5
KBOFO = KBOFO * 100

C WRITE VALUES FOR THE PERIOD IF THINNING IS NOT DUE.

C
WRITE (6,94) KAGEO,KOENO,KBASO,OBHO,KHTSO,KTOTO,KCFMO,KBOFO
DBHT = OBHO
BAST = BASO
DENT = DENO
120 CONTINUE
125 REST = OLEV
130 CONTINUE

C ADD FINAL CUTS TO TOTAL YIELDS AND WRITE TOTAL YIELDS.

C
135 JSTF = JSTF + JTOTO
CFMO = JCFMO
IF(CFMO .LT. COMCU) GO TO 140
JSMC = JSMC + JCFMO
140 BOFO = JBDOFO
IF(BOFO .LT. COMBF) GO TO 145
JSBD = JSBD + JBDOFO
145 WRITE (6,150) JSTF,JSMC,JSBD
150 FORMAT (1H0,/,67X,12HTOTAL YIELDS,18X,16,4X,16,6X,17)
WRITE (6,155) COMCU,COMBF
155 FORMAT (1H0,/,11X,44HMINIMUM CUTS FOR INCLUSION IN TOTAL YIELDS--
1,F6.0,15H CUBIC FEET AND,F7.0,11H BOARD FEET)
WRITE (6,156)
156 FORMAT (1H0,10X,66HMERCH. CU. FT. - TREES 5.0 INCHES 0.8.H. AND LA
RGER TO 4-INCH TOP.)
WRITE (6,157)
157 FORMAT (1H0,10X,59HBD. FT. - TREES 8.0 INCHES 0.8.H. AND LARGER TO
1 6-INCH TOP.)

C PREPARE FOR NEXT TABLE OF THE TEST.

C
AGEO = VAR(1)
DBHO = VAR(2)
DENO = VAR(3)
JCYCL = JTEM
160 CONTINUE
GO TO 200
170 WRITE (6,175)
175 FORMAT (1H1,/,10X,66HEXECUTION STOPPED BECAUSE OF NEGATIVE OR ZE
1RO ITEM ON A DATA CARD.)
200 CALL EXIT
ENO

```

SUBROUTINE SPRCUT
C TO ESTIMATE INCREASE IN AVERAGE D.B.H. DUE TO THINNING.
C
COMMON BA,BAST,CUFT,DBHD,DBHT,DENO,FCTR,HITE,GIDE,PRET,PRGD,REST,S
ITAND,VDM
C
IF(DBHD .LT. 9.4) GO TO 30
C
C COMPUTE D.B.H. IF DBHD IS LARGE ENOUGH FOR BASAL AREA TO REMAIN CONSTANT.
C
PRET = 100.0
DO 21 KJ=1,100
C-----STATEMENTS FOR DBHE AND PDBHE ARE SPECIES-SPECIFIC.
C
IF(PRET .LT. 50.0) GO TO 5
DBHE = 0.02666 + 1.30655 * DBHD - 0.00306 * PRET * DBHD
GO TO 11
5 PDBHE = 0.33206 + 0.98346 * ALOG10(DBHD) - 0.14710 * ALOG10(PRET)
DBHE = 10.0 ** PDBHE
11 IDBHE = DBHE * 10.0 + 0.5
DBHE = IDBHE
DBHE = DBHE * 0.1
DENE = DENO * PRET * 0.01
NOENE = DENE + 0.5
DENE = NOENE
BASE = 0.0054542 * DBHE * DBHE * DENE
NBASE = BASE * 10.0 + 0.5
BASE = NBASE
BASE = BASE * 0.1
TMPY = 0.0054542 * DBHE * DBHE
TEM = BASE - REST
IF(KJ .EQ. 1 .AND. TEM .LT. 0.0) GO TO 90
IF(TEM .LE. TMPY) GO TO 70
IF(TEM .LT. 4.0) GO TO 20
PRET = PRET - 1.0
GO TO 21
20 PRET = PRET - 0.3
21 CONTINUE
GO TO 7D
C
C COMPUTE D.B.H. IF BASAL AREA INCREASES WITH D.B.H.
C
30 PRET = 40.0
IF(DBHD .GT. 7.0) PRET = 70.0
DO 65 J=1,100
C-----STATEMENTS FOR DBHE AND PDBHE ARE SPECIES-SPECIFIC.
C
IF(PRET .GE. 50.0) GO TO 40
PDBHE = 0.33206 + 0.98346 * ALOG10(DBHD) - 0.14710 * ALOG10(PRET)
DBHE = 10.0 ** PDBHE
GO TO 45
40 DBHE = 0.02666 + 1.30655 * DBHD - 0.00306 * PRET * DBHD
45 IDBHE = DBHE * 10.0 + 0.5
DBHE = IDBHE
DBHE = DBHE * 0.1
DENE = DENO * (PRET * 0.01)
NOENE = DENE + 0.5
DENE = NOENE
BASE = 0.0054542 * DBHE * DBHE * DENE
NBASE = BASE * 10.0 + 0.5
BASE = NBASE
BASE = BASE * 0.1
C-----CHANGE STATEMENTS FOR BREAK, BUST AND FIRST 3 STATEMENTS FOR DBHP
C-----IF OTHER GROWING STOCK LEVEL BASE THAN TABLE I IS USED.
C
BREAK = 49.9 * REST / GIDE
IF(BASE .GT. BREAK) GO TO 50
DBHP = (GIDE / REST) * (0.08682 * BASE) + 0.94636
GO TO 52
50 BUST = 66.2 * (REST / GIDE)
IF(BASE .GT. BUST) GO TO 51
DBHP = (GIDE / REST) * (0.10938 * BASE) - 0.17858
GO TO 52
51 TMPY = BASE * (GIDE / REST)
TEM = TMPY * TMPY
DBHP = 19.04740 * TMPY - 0.26673 * TEM + 0.0012539 * TEM * TMPY
1 - 448.76833
IF(TMPY .GT. GIDE) DBHP = DBHD + 0.8
52 IDBHP = DBHP * 10.0 + 0.5
DBHP = IDBHP
DBHP = DBHP * 0.1
IF(DBHP - DBHE) 60,70,61
60 PRET = PRET * 1.02
IF(PRET .GT. 100.0) GO TO 90
GO TO 65
61 PRET = PRET * 0.98
65 CONTINUE
70 DBHT = DBHE
C
C COMPUTE POST-THINNING BASAL AREA.
C
C-----CHANGE TWO IF STATEMENTS AND STATEMENTS FOR SOFT IF DIFFERENT
C-----GROWING STOCK LEVEL BASE IS USED.
C
IF(DBHT .GT. 5.0) GO TO 75
SOFT = 11.58495 * DBHT - 11.09724
GO TO 76
75 IF(DBHT .GE. 10.0) GO TO 77
TEM = DBHT * DBHT
SOFT = 7.76226 * DBHT + 0.85289 * TEM - 0.07952 * TEM * DBHT - 3.45624
76 BAST = (REST / GIDE) * SQFT
GO TO 80
77 BAST = REST
80 RETURN
90 PRET = 100.0
RETURN
END

```

Appendix II: Output of SPRYLD

Two-Cut Shelterwood

YIELDS PER ACRE OF MANAGED, EVEN-AGED STANDS OF ENGELMANN SPRUCE AND SUBALPINE FIR

SITE INDEX 80, 30-YEAR CUTTING CYCLE

THINNING LEVELS= INITIAL - 80., SUBSEQUENT - 80.

ENTIRE STAND BEFORE AND AFTER THINNING								PERIODIC INTERMEDIATE CUTS							
STAND AGE (YEARS)	TREES NO.	BASAL AREA SQ.FT.	AVERAGE D.B.H. IN.	AVERAGE HEIGHT FT.	TOTAL VOLUME CU.FT.	MERCHANT-ABLE VOLUME CU.FT.	SAWTIMBER VOLUME 80.FT.	TREES NO.	BASAL AREA SQ.FT.	TOTAL VOLUME CU.FT.	MERCHANT-ABLE VOLUME CU.FT.	SAWTIMBER VOLUME 80.FT.			
30	850	94	4.5	28	1010	340	0	536	42	330	0	0			
30	314	52	5.5	29	680	340	0								
40	311	78	6.8	38	1260	900	0								
50	305	106	8.0	45	2030	1650	4200	146	53	1110	920	2600			
60	295	133	9.1	53	2920	2530	8300								
60	149	80	9.9	53	1810	1610	5700								
70	145	99	11.2	59	2510	2310	9200								
80	145	122	12.4	65	3370	3150	13600								
90	145	146	13.6	70	4350	4120	18700	90	66	1910	1780	7600			
90	55	80	16.3	71	2440	2340	11100								
100	55	95	17.8	75	3000	2910	14500								
110	55	112	19.3	79	3610	3520	18300	37	68	2240	2170	11200			
120	55	130	20.8	82	4290	4200	22500								
120	18	62	25.2	84	2050	2030	11300								
130	18	72	27.1	87	2420	2400	13700								
140	18	83	29.0	89	2830	2810	16500								
150	18	94	30.9	91	3280	3250	19500	TOTAL YIELDS					8870	8120	40900

MINIMUM CUTS FOR INCLUSION IN TOTAL YIELDS-- 400. CUBIC FEET AND 2000. BOARD FEET

MERCH. CU. FT. - TREES 5.0 INCHES D.B.H. AND LARGER TO 4-INCH TOP.

80. FT. - TREES 8.0 INCHES D.B.H. AND LARGER TO 6-INCH TOP.

YIELDS PER ACRE OF MANAGED, EVEN-AGED STANDS OF ENGELMANN SPRUCE AND SUBALPINE FIR

SITE INDEX 80, 30-YEAR CUTTING CYCLE

THINNING LEVELS= INITIAL - 80., SUBSEQUENT - 120.

ENTIRE STAND BEFORE AND AFTER THINNING								PERIODIC INTERMEDIATE CUTS							
STAND AGE (YEARS)	TREES NO.	BASAL AREA SQ.FT.	AVERAGE D.B.H. IN.	AVERAGE HEIGHT FT.	TOTAL VOLUME CU.FT.	MERCHANT- ABLE VOLUME CU.FT.	SAWTIMBER VOLUME 80.FT.	TREES NO.	BASAL AREA SQ.FT.	TOTAL VOLUME CU.FT.	MERCHANT- ABLE VOLUME CU.FT.	SAWTIMBER VOLUME 80.FT.			
30	850	94	4.5	28	1010	340	0	536	42	330	0	0			
30	314	52	5.5	29	680	340	0								
40	311	78	6.8	38	1260	900	0								
50	305	106	8.0	45	2030	1650	4200	67	14	260	170	0			
60	295	133	9.1	53	2920	2530	8500								
60	228	119	9.8	53	2660	2360	8500								
70	218	141	10.9	59	3520	3220	12800								
80	218	171	12.0	65	4670	4350	18700								
90	218	204	13.1	70	5990	5640	25500	126	83	2340	2140	9000			
90	92	121	15.5	71	3650	3500	16500								
100	92	142	16.8	75	4570	4400	21800								
110	92	164	18.1	79	5320	5160	26500	60	93	3090	2960	15200			
120	92	189	19.4	82	6240	6080	32300								
120	32	96	23.4	83	3150	3120	17100								
130	32	110	25.1	86	3700	3670	20700								
140	32	125	26.8	89	4310	4270	24800								
150	32	142	28.5	91	4960	4910	29200	TOTAL YIELDS					10980	10010	53400

MINIMUM CUTS FOR INCLUSION IN TOTAL YIELDS-- 400. CUBIC FEET AND 2000. BOARD FEET

MERCH. CU. FT. - TREES 5.0 INCHES D.B.H. AND LARGER TO 4-INCH TOP.

80. FT. - TREES 8.0 INCHES D.B.H. AND LARGER TO 6-INCH TOP.

YIELOS PER ACRE OF MANAGED, EVEN-AGED STANOS OF ENGELMANN SPRUCE AND SUBALPINE FIR

SITE INDEX 80, 30-YEAR CUTTING CYCLE

THINNING LEVELS= INITIAL - 120., SUBSEQUENT - 80.

STANO AGE (YEARS)	ENTIRE STANO BEFORE AND AFTER THINNING						PERIODIC INTERMEDIATE CUTS					
	TREES NO.	BASAL AREA SQ.FT.	AVERAGE O.B.H. IN.	AVERAGE HEIGHT FT.	TOTAL VOLUME CU.FT.	MERCHANT- ABLE VOLUME CU.FT.	SAWTIMBER VOLUME BO.FT.	TREES NO.	BASAL AREA SQ.FT.	TOTAL VOLUME CU.FT.	MERCHANT- ABLE VOLUME CU.FT.	SAWTIMBER VOLUME BO.FT.
30	850	94	4.5	28	1010	340	0					
30	505	72	5.1	29	870	340	0	345	22	140	0	0
40	498	108	6.3	37	1620	1050	0					
50	485	141	7.3	45	2540	1940	0					
60	466	175	8.3	52	3660	3040	8700					
60	172	78	9.1	52	1740	1510	4800	294	97	1920	1530	3900
70	167	99	10.4	59	2470	2230	8400					
80	167	123	11.6	64	3350	3100	12800					
90	167	149	12.8	69	4390	4120	18200					
90	61	80	15.5	70	2420	2320	10800	106	69	1970	1800	7400
100	61	96	17.0	75	3100	2990	14700					
110	61	113	18.4	79	3660	3550	18100					
120	61	130	19.8	82	4320	4210	22200					
120	20	63	24.0	83	2060	2040	11200	41	67	2260	2170	11000
130	20	73	25.9	86	2460	2430	13700					
140	20	84	27.8	89	2890	2860	16600					
150	20	96	29.7	91	3360	3320	19800					
TOTAL YIELOS										9650	8820	42100

MINIMUM CUTS FOR INCLUSION IN TOTAL YIELOS-- 400. CUBIC FEET AND 2000. BOARD FEET

MERCH. CU. FT. - TREES 5.0 INCHES O.B.H. AND LARGER TO 4-INCH TOP.

80. FT. - TREES 8.0 INCHES O.B.H. AND LARGER TO 6-INCH TOP.

YIELOS PER ACRE OF MANAGED, EVEN-AGED STANOS OF ENGELMANN SPRUCE AND SUBALPINE FIR

SITE INDEX 80, 30-YEAR CUTTING CYCLE

THINNING LEVELS= INITIAL - 120., SUBSEQUENT - 120.

STANO AGE (YEARS)	ENTIRE STANO BEFORE AND AFTER THINNING						PERIODIC INTERMEDIATE CUTS					
	TREES NO.	BASAL AREA SQ.FT.	AVERAGE O.B.H. IN.	AVERAGE HEIGHT FT.	TOTAL VOLUME CU.FT.	MERCHANT- ABLE VOLUME CU.FT.	SAWTIMBER VOLUME BO.FT.	TREES NO.	BASAL AREA SQ.FT.	TOTAL VOLUME CU.FT.	MERCHANT- ABLE VOLUME CU.FT.	SAWTIMBER VOLUME BO.FT.
30	850	94	4.5	28	1010	340	0					
30	505	72	5.1	29	870	340	0	345	22	140	0	0
40	498	108	6.3	37	1620	1050	0					
50	485	141	7.3	45	2540	1940	0					
60	466	175	8.3	52	3660	3040	8700					
60	259	117	9.1	52	2570	2230	7300	207	58	1090	810	1400
70	249	141	10.2	59	3480	3130	11800					
80	249	173	11.3	64	4680	4300	17800					
90	249	205	12.3	69	5960	5570	24400					
90	103	120	14.6	70	3600	3430	15900	146	85	2360	2140	8500
100	103	142	15.9	75	4540	4360	20900					
110	103	166	17.2	78	5410	5220	26300					
120	103	190	18.4	82	6310	6120	31900					
120	35	96	22.4	83	3160	3120	16900	68	94	3150	3000	15000
130	35	110	24.0	86	3710	3670	20400					
140	35	125	25.6	88	4300	4260	24300					
150	35	141	27.2	91	4940	4890	28700					
TOTAL YIELOS										11680	10840	52200

MINIMUM CUTS FOR INCLUSION IN TOTAL YIELOS-- 400. CUBIC FEET AND 2000. BOARD FEET

MERCH. CU. FT. - TREES 5.0 INCHES O.B.H. AND LARGER TO 4-INCH TOP.

80. FT. - TREES 8.0 INCHES O.B.H. AND LARGER TO 6-INCH TOP.

Three-Cut Shelterwood

YIELOS PER ACRE OF MANAGED, EVEN-AGED STANOS OF ENGELMANN SPRUCE AND SUBALPINE FIR

SITE INDEX 80, 30-YEAR CUTTING CYCLE

THINNING LEVELS= INITIAL - 80., SUBSEQUENT - 80.

STANO AGE (YEARS)	ENTIRE STANO BEFORE AND AFTER THINNING							PERIOOIC INTERMEOTATE CUTS				
	TREES NO.	BASAL AREA SQ.FT.	AVERAGE O.B.H. IN.	AVERAGE HEIGHT FT.	TOTAL VOLUME CU.FT.	MERCHANT- ABLE VOLUME CU.FT.	SAWTIMBER VOLUME 80.FT.	TREES NO.	BASAL AREA SQ.FT.	TOTAL VOLUME CU.FT.	MERCHANT- ABLE VOLUME CU.FT.	SAWTIMBER VOLUME 80.FT.
30	850	94	4.5	28	1010	340	0					
30	314	52	5.5	29	680	340	0	536	42	330	0	0
40	311	78	6.8	38	1260	900	0					
50	305	106	8.0	45	2030	1650	4200					
60	295	133	9.1	53	2920	2530	8300					
60	149	80	9.9	53	1810	1610	5700	146	53	1110	920	2600
70	145	99	11.2	59	2510	2310	9200					
80	145	122	12.4	65	3370	3150	13600					
90	145	146	13.6	70	4350	4120	18700					
90	40	64	17.1	71	1970	1900	9200	105	82	2380	2220	9500
100	40	76	18.7	76	2410	2340	11800					
110	40	90	20.3	80	2910	2840	14900					
120	40	105	21.9	83	3460	3400	18400					
120	13	49	26.4	84	1620	1610	9000	27	56	1840	1790	9400
130	13	57	28.4	87	1930	1910	11000					
140	13	66	30.4	90	2250	2230	13200					
150	13	75	32.5	92	2620	2600	15700					
TOTAL YIELOS										8280	7530	37200

MINIMUM CUTS FOR INCLUSION IN TOTAL YIELOS-- 400. CUBIC FEET AND 2000. BOARD FEET

MERCH. CU. FT. - TREES 5.0 INCHES O.B.H. AND LARGER TO 4-INCH TOP.

80. FT. - TREES 8.0 INCHES O.B.H. AND LARGER TO 6-INCH TOP.

YIELOS PER ACRE OF MANAGED, EVEN-AGED STANOS OF ENGELMANN SPRUCE AND SUBALPINE FIR

SITE INDEX 80, 30-YEAR CUTTING CYCLE

THINNING LEVELS= INITIAL - 80., SUBSEQUENT - 120.

STANO AGE (YEARS)	ENTIRE STANO BEFORE AND AFTER THINNING							PERIOOIC INTERMEOTATE CUTS				
	TREES NO.	BASAL AREA SQ.FT.	AVERAGE O.B.H. IN.	AVERAGE HEIGHT FT.	TOTAL VOLUME CU.FT.	MERCHANT- ABLE VOLUME CU.FT.	SAWTIMBER VOLUME 80.FT.	TREES NO.	BASAL AREA SQ.FT.	TOTAL VOLUME CU.FT.	MERCHANT- ABLE VOLUME CU.FT.	SAWTIMBER VOLUME 80.FT.
30	850	94	4.5	28	1010	340	0					
30	314	52	5.5	29	680	340	0	536	42	330	0	0
40	311	78	6.8	38	1260	900	0					
50	305	106	8.0	45	2030	1650	4200					
60	295	133	9.1	53	2920	2530	8500					
60	228	119	9.8	53	2660	2360	8500	67	14	260	170	0
70	218	141	10.9	59	3520	3220	12800					
80	218	171	12.0	65	4670	4350	18700					
90	218	204	13.1	70	5990	5640	25500					
90	66	96	16.3	71	2930	2820	13400	152	108	3060	2820	12100
100	66	113	17.7	76	3570	3450	17300					
110	66	131	19.1	79	4260	4140	21500					
120	66	151	20.5	83	5010	4900	26300					
120	23	76	24.6	84	2500	2480	13700	43	75	2510	2420	12600
130	23	87	26.4	87	2950	2920	16700					
140	23	100	28.2	89	3440	3400	19900					
150	23	113	30.0	92	3960	3920	23500					
TOTAL YIELOS										10120	9160	48200

MINIMUM CUTS FOR INCLUSION IN TOTAL YIELOS-- 400. CUBIC FEET AND 2000. BOARD FEET

MERCH. CU. FT. - TREES 5.0 INCHES O.B.H. AND LARGER TO 4-INCH TOP.

80. FT. - TREES 8.0 INCHES O.B.H. AND LARGER TO 6-INCH TOP.

YIELDS PER ACRE OF MANAGED, EVEN-AGED STANOS OF ENGELMANN SPRUCE AND SUBALPINE FIR

SITE INDEX 80, 30-YEAR CUTTING CYCLE

THINNING LEVELS= INITIAL - 120., SUBSEQUENT - 80.

ENTIRE STAND BEFORE AND AFTER THINNING								PERIODIC INTERMEDIATE CUTS				
STAND AGE (YEARS)	TREES NO.	BASAL AREA SQ.FT.	AVERAGE D.B.H. IN.	AVERAGE HEIGHT FT.	TOTAL VOLUME CU.FT.	MERCHANT- ABLE VOLUME CU.FT.	SAWTIMBER VOLUME 80.FT.	TREES NO.	BASAL AREA SQ.FT.	TOTAL VOLUME CU.FT.	MERCHANT- ABLE VOLUME CU.FT.	SAWTIMBER VOLUME 80.FT.
30	850	94	4.5	28	1010	340	0	345	22	140	0	0
30	505	72	5.1	29	870	340	0					
40	498	108	6.3	37	1620	1050	0					
50	485	141	7.3	45	2540	1940	0					
60	466	175	8.3	52	3660	3040	8700	294	97	1920	1530	3900
60	172	78	9.1	52	1740	1510	4800					
70	167	99	10.4	59	2470	2230	8400					
80	167	123	11.6	64	3350	3100	12800					
90	167	149	12.8	69	4390	4120	18200	122	85	2420	2230	9300
90	45	64	16.2	71	1970	1890	8900					
100	45	78	17.8	75	2460	2390	11800					
110	45	92	19.4	79	2990	2910	15100					
120	45	107	20.9	82	3550	3480	18500	30	54	1820	1760	9000
120	15	53	25.4	84	1730	1720	9500					
130	15	61	27.4	87	2060	2040	11700					
140	15	71	29.4	89	2430	2400	14100					
150	15	81	31.4	91	2820	2790	16800					
TOTAL YIELDS										9120	8310	39000

MINIMUM CUTS FOR INCLUSION IN TOTAL YIELDS-- 400. CUBIC FEET AND 2000. BOARD FEET

MERCH. CU. FT. - TREES 5.0 INCHES O.B.H. AND LARGER TO 4-INCH TOP.

80. FT. - TREES 8.0 INCHES O.B.H. AND LARGER TO 6-INCH TOP.

YIELDS PER ACRE OF MANAGED, EVEN-AGED STANOS OF ENGELMANN SPRUCE AND SUBALPINE FIR

SITE INDEX 80, 30-YEAR CUTTING CYCLE

THINNING LEVELS= INITIAL - 120., SUBSEQUENT - 120.

ENTIRE STAND BEFORE AND AFTER THINNING								PERIODIC INTERMEDIATE CUTS				
STAND AGE (YEARS)	TREES NO.	BASAL AREA SQ.FT.	AVERAGE O.B.H. IN.	AVERAGE HEIGHT FT.	TOTAL VOLUME CU.FT.	MERCHANT-ABLE VOLUME CU.FT.	SAWTIMBER VOLUME 80.FT.	TREES NO.	BASAL AREA SQ.FT.	TOTAL VOLUME CU.FT.	MERCHANT-ABLE VOLUME CU.FT.	SAWTIMBER VOLUME 80.FT.
30	850	94	4.5	28	1010	340	0	345	22	140	0	0
30	505	72	5.1	29	870	340	0					
40	498	108	6.3	37	1620	1050	0					
50	485	141	7.3	45	2540	1940	0					
60	466	175	8.3	52	3660	3040	8700	207	58	1090	810	1400
60	259	117	9.1	52	2570	2230	7300					
70	249	141	10.2	59	3480	3130	11800					
80	249	173	11.3	64	4680	4300	17800					
90	249	205	12.3	69	5960	5570	24400	174	109	3050	2790	11400
90	75	96	15.3	71	2910	2780	13000					
100	75	114	16.7	75	3690	3550	17400					
110	75	134	18.1	79	4360	4230	21600					
120	75	156	19.5	82	5160	5030	26500	50	80	2650	2550	13000
120	25	76	23.6	83	2510	2480	13500					
130	25	88	25.4	86	2970	2940	16500					
140	25	101	27.2	89	3470	3430	19900					
150	25	115	29.0	91	4010	3970	23600					
TOTAL YIELDS										10940	10120	48000

MINIMUM CUTS FOR INCLUSION IN TOTAL YIELDS-- 400. CUBIC FEET AND 2000. BOARD FEET

MERCH. CU. FT. - TREES 5.0 INCHES O.B.H. AND LARGER TO 4-INCH TOP.

80. FT. - TREES 8.0 INCHES O.B.H. AND LARGER TO 6-INCH TOP.

Appendix III: Listing of Subroutine ESSF

SUBROUTINE ESSF

LOCATION FOR ALL SPECIES - SPECIFIC STATEMENTS APPLICABLE TO ENGELMANN
SPRUCE - SUBALPINE FIR IN COLORADO AND WYOMING.

```
COMMON ADD,AGE(2),AGED,BA(2),BAS(2),BASO,BAST,BAUS,BFMRCH,BFVDL,
1CFVOL,OATE(6),DBH(2),DBHE,DBHO,DBHT,DEN(2),DENO,DENT,DMUS,FBA(2),
2FCTR(2),FDM(2),FON(2),FHT(2),FORET(19),FVL(2),HT(2),HTCUM,HTSD,
3HTST,KAK,KNO,MIN,MNK,NBK,NCMP,NSUB,NWGP,PDBHE,PRET,PRDDI(2),REST,
4SAVE,SBAR8,SBARE,SBARG,SBAS,SITE,SLAND,TBA(2),TDM(2),TEM,TIME,TM8R
5,TMPD,TOT(2),TDTD,TDTT,TVL(2),VDM(2),VLUS,DMR(2)
COMMON ABFAG(5,15),ACINT(5),ADJ(5),AGETH(5,14),ALLCF(5,14),ALDWC(5
1),ALWBF(5),AMCAG(5,15),ANCUT(5,14),AREA(5,14),RDMAT(5),BFAGE(5,15)
2,RFINT(5),CFAGE(5,15),CFBF(5,14),COMBF(5),COMCU(5),CUCY(5),CUINT(5
3),CUMAI(5),DBHTH(5,14),DELAY(5),DENTH(5,14),OLEV(5),FNBD(5),
4FNCU(5),GRDWB(5,2,14),GRDWC(5,2,14),GVLBF(5),GVLUC(5),INVL(5,3,14)
5,NSI(5),DPBO(5),CPCU(5),PAIBD(5),PAICU(5),PDDR(5),REGN(5,3,14),
6RINT(5),SARSP(5),SBF(5),SHELT(5,2,14),SHWD(5,2,14),SMC(5),SMSP(5),
7SUBBF(5,14),SUBCF(5,14),SUMCF(5),SYST(5),THIN(5),VLLV(5,3,14),
8WGNUM(5),WGPDES(5,20),WGNPM(5,3),SPNUM(5),TPB(5,7),PASP(5,7)
COMMON ACBAR(7),ARBK(7),BASR(7,14),BFTH(7,14),CMTH(7,27),CUTA(7,2
17),CUTB(7,27),HELPT(7,27),NSBK(7),OPEN(7,27),PBRSI(7,14),PDCFN(7,27
2),PDCFR(7,27),PSPLT(7,27),PUNC(7,27),SARETY(7,35),SLVG(7,27),SPLT(
37,27),TMTY(7),UNCML(7,27),PARB(7),PARTY(7,35)
COMMON ACFN(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBD(5,7
CDMMN ACFN(5,7,15),ACRGN(5,7,15),ACSI(5,7,14),ACSP(5,7),GRBD(5,7
1,15),GRMC(5,7,15),PS(5,7,14),STYP(35),TYPNM(35,5),PASI(5,7,14)
```

COMMON /BLKO/ IJ,IK,KI,VOL,TVOL

GO TO (10,20,30,40,50,60,70,80,90,100,110,120), IJ

SECTION 1 - FIND TOTAL CUBIC FOOT VOLUME.

```
10 D2H = OBH(IK) * OBH(IK) * HT(IK)
IF(D2H .GE. 22500.0) GO TO 11
TOT(IK) = (0.0023575 * O2H - 0.00524 * BAS(IK) + 0.34480) * OEN(IK)
GO TO 12
11 TGT(IK) = (0.0020103 * O2H - 0.01052 * BAS(IK) + 7.60196) * OEN(IK)
12 RETURN
```

SECTION 2 - VOLUME CONVERSION FACTORS.

MERCH. CU. FT. - TREES 6.0 INCHES D.B.H. AND LARGER TO 4-INCH TOP.

HD. FT. - TREES 10.0 INCHES D.B.H. AND LARGER TO 8-INCH TOP.

```
20 DO 21 J=1,2
FCTR(J) = 0.0
21 PRDD(J) = D.0
DO 26 I=1,KNO
IF(VDM(I) .LE. 4.99) GO TO 26
FCTR(I) = 3.82375 + 3.45569 / VOM(I) + D.C0313 * VDM(I) * VDM(I)
1 - 28.86783 / (VDM(I) * VDM(I))
IF(FCTR(I) .GT. 0.99) FCTR(I) = C.99
24 IF(VDM(I) .LE. 7.99) GO TO 26
IF(VOM(I) .GE. 16.5) GO TO 25
PRDD(I) = 4.59159 - 214.06370 / (VOM(I) * VDM(I)) + D.39782 *
1 ALOG10(BA(I))
GO TO 26
25 PRDD(I) = 8.59422 - 19.54507 / SQRT(VOM(I)) + 0.44432 * ALDGL0(BA
111)
26 CONTINUE
RETURN
```

SECTION 3 - GROWTH FOR NEXT PERIOD.

```
30 DO 35 I=1,2
TMOY = AGE(I) + TIME
IF(TMOY .LT. TEM) GO TO 35
FDM(I) = 1.62917 + 1.03371 * DBH(I) + 0.01304 * SITE - 0.90669 *
1 ALOG10(SBAS)
31 IF(OBH(I) .GE. 10.0) GO TO 32
FON(I) = (-0.03967 + 0.00382 * OBH(I) * SBAS) * 0.01
IF(FON(I) .LT. 0.0) FON(I) = 0.0
FON(I) = OEN(I) * (1.0 - FON(I))
MNK = FDM(I) + 0.5
FDM(I) = MNK
GO TO 33
32 FON(I) = OEN(I)
33 FBA(I) = 0.0054542 * FOM(I) * FDM(I) * FON(I)
IF(AGE(I) .GE. 100.0) GO TO 37
FHT(I) = -13.71751 + 0.15087 * SITE + 0.00126 * AGE(I) * AGE(I) +
1 D.01371 * AGE(I) * SITE - 0.00006 * AGE(I) * AGE(I) * SITE
GO TO 38
37 FHT(I) = 0.91859 - 100.43601 / AGE(I) + 0.62318 * ALOG10(SITE) +
1 40.08154 * ALOG10(SITE) / AGE(I)
FHT(I) = 10.0 ** FHT(I)
38 D2H = FOM(I) * FDM(I) * FHT(I)
IF(D2H .GE. 22500.0) GO TO 34
FVL(I) = (0.0023575 * O2H - 0.00524 * FBA(I) + 0.34480) * FON(I)
GO TO 35
34 FVL(I) = (0.0020103 * O2H - 0.01052 * FBA(I) + 7.60196) * FON(I)
35 CONTINUE
RETURN
```

SECTION 4 - FUTURE UNTHINNED UNDERSTORY IF OVERSTORY REDUCED NOW.

```
40 DMUS = 1.62917 + 1.03371 * OBH(2) + 0.01304 * SITE - 0.90669 *
1 ALOG10(BAS(2))
```

```
IF(DBH(2) .GE. 10.0) GO TO 41
DNUS = (-0.03967 + 0.00382 * DBH(2) * BAS(2)) * 0.01
IF(DNUS .LT. 0.0) DNUS = 0.0
ONUS = DEN(2) * (1.0 - DNUS)
MNK = DNUS + 0.5
DNUS = MNK
GO TO 42
41 DNUS = DEN(2)
42 BAUS = D.0054542 * DMUS * DMUS * DNUS
IF(AGE(2) .GE. 100.0) GO TO 47
HTUS = -13.71751 + 0.15087 * SITE + 0.00126 * AGE(2) * AGE(2) +
1 0.01371 * AGE(2) * SITE - 0.00006 * AGE(2) * AGE(2) * SITE
GO TO 48
47 HTUS = 0.91859 - 100.43601 / AGE(2) + 0.62318 * ALOG10(SITE) +
1 40.08154 * ALOG10(SITE) / AGE(2)
HTUS = 10.0 ** HTUS
48 D2H = DMUS * DMUS * HTUS
IF(D2H .GE. 22500.0) GO TO 43
VLUS = (0.0023575 * O2H - 0.00524 * BAUS + 0.34480) * DNUS
GO TO 44
43 VLUS = (0.0020103 * O2H - 0.01052 * BAUS + 7.60196) * DNUS
44 RETURN
```

SECTION 5 - NEW D.B.H. AFTER THINNING.

```
50 IF(PRET .LT. 50.0) GO TO 51
DBHE = 0.02666 + 1.30655 * DBHO - 0.00306 * PRET * DBHO
GO TO 52
51 PDBHE = 0.33206 + 0.98346 * ALDGL0(DBHO) - 0.14710 * ALDGL0(PRET)
DBHE = 10.0 ** PDBHE
52 RETURN
```

SECTION 6 - CUBIC FEET AS BYPRODUCT OF SAWLOG CUT.

```
60 ADD = VCL * (1.54375 + 11.43324 / DBH(KI))
ADD = TVGL - ADD
IF(ADD .LT. COMCU(KAK)) ADD = 0.0
RETURN
```

SECTION 7 - VOLUME IF THINNED NOW AND IF THINNED IN TIME YEARS.

```
70 HT(KI) = HT(KI) - 1.91392 + 17.77922 * SQRT(1.0 / PRET)
TEM = TBA(KI) / (0.0054542 * TOM(KI) * TOM(KI))
D2H = TOM(KI) * TOM(KI) * HT(KI)
IF(D2H .GE. 22500.0) GO TO 71
TVL(KI) = (0.0023575 * O2H - 0.00524 * TBA(KI) + 0.34480) * TEM
GO TO 72
71 TVL(KI) = (0.0020103 * O2H - 0.01052 * TBA(KI) + 7.60196) * TEM
72 RETURN
```

SECTION 8 - STATUS AT END OF PERIOD IF THINNED AT START OF PERIOD.

```
80 J = TIME / RINT(KAK)
DO 83 I=1,J
IF(T3A(I) .LE. 0.0) GO TO 83
FHT(I) = HT(I) - 1.91392 + 17.77922 * SQRT(1.0 / SAVE)
FOM(I) = 1.62917 + 1.03371 * TOM(I) + 0.01304 * SITE - 0.90669 *
1 ALOG10(TBA(I))
IF(AGE(KI) .GE. 100.0) GO TO 87
FHT(I) = -13.71751 + 0.15087 * SITE + 0.00126 * AGE(KI) * AGE(KI) +
1 + 0.01371 * AGE(KI) * SITE - 0.00006 * AGE(KI) * AGE(KI) * SITE
GO TO 88
87 FHT(I) = 0.91859 - 100.43601 / AGE(KI) + 0.62318 * ALOG10(SITE) +
1 40.08154 * ALOG10(SITE) / AGE(KI)
FHT(I) = 10.0 ** FHT(I)
88 MNK = (TBA(I) / (0.0054542 * TOM(I) * TOM(I))) + 0.5
IF(TOM(I) .LT. 10.0) GO TO 81
FON(I) = MNK
GO TO 82
81 FON(I) = (-0.03967 + 0.00382 * TOM(I) * TBA(I)) * 0.01
IF(FON(I) .LT. 0.0) FON(I) = 0.0
TEM = MNK
NMK = TEM * (1.0 - FON(I)) + 0.5
FOM(I) = NMK
82 FBA(I) = FON(I) * 0.0054542 * FOM(I) * FDM(I)
TOM(I) = FOM(I)
TBA(I) = FBA(I)
HT(I) = FHT(I)
AGE(KI) = AGE(KI) + RINT(KAK)
83 CONTINUE
D2H = FOM(I) * FDM(I) * FHT(I)
IF(D2H .GE. 22500.0) GO TO 84
FVL(I) = (0.0023575 * O2H - 0.00524 * FBA(I) + 0.34480) * FON(I)
GO TO 85
84 FVL(I) = (0.0020103 * O2H - 0.01052 * FBA(I) + 7.60196) * FON(I)
85 RETURN
```

SECTION 9 - HEIGHT AND VOLUME BEFORE THINNING.

```
90 IF(AGED .GE. 100.0) GO TO 91
HTSO = -13.71751 + 0.15087 * SITE + 0.00126 * AGE0 * AGE0 +
1 0.01371 * AGE0 * SITE - 0.00006 * AGE0 * AGE0 * SITE
GO TO 92
91 HTSO = 0.91859 - 100.43601 / AGE0 + 0.62318 * ALOG10(SITE) +
1 40.08154 * ALOG10(SITE) / AGE0
HTSO = 10.0 ** HTSO
92 HTSO = HTSC + HTCUM
D2H = OBHO * OBHO * HTSO
```

```

      IF(02H .GE. 22500.0) GO TO 93
      TOT0 = (0.0023575 * 02H - 0.00524 * 8AS0 + 0.34480) * 0ENO
      GO TO 94
93  TOT0 = (0.0020103 * 02H - 0.01052 * 8AS0 + 7.60196) * 0ENO
94  RETURN
C
C SECTION 10 - HEIGHT AND TOTAL CUBIC FEET PER ACRE AFTER THINNING.
C
100 A00HT = - 1.81392 + 17.77922 * SQRT(1.0 / PRET)
   HTCUM = HTCUM + A00HT
   HTST = HTS0 + A00HT
   02H = 08HT * 08HT * HTST
   IF(02H .GE. 22500.0) GO TO 101
   TOT1 = (0.0023575 * 02H - 0.00524 * 8AST + 0.34480) * 0ENT
   GO TO 102
101 TOT1 = (0.0020103 * 02H - 0.01052 * 8AST + 7.60196) * 0ENT
102 RETURN
C
C SECTION 11 - 0.8.H. AT END OF PROJECTION PERIOD.
C
110 08H0 = 1.62917 + 1.03371 * 08HT + 0.01304 * SITE - 0.90669 *
      1 ALOG10(8AST)
      RETURN
C
C SECTION 12 - MORTALITY AS A PERCENTAGE OF INITIAL DENSITY.
C
120 DENO = (-0.03967 + 0.00382 * 08HT * 8AST) * 0.01
      RETURN
      ENO

```


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1975. Yield tables for managed stands of spruce-fir in the central Rocky Mountains. USDA For. Serv. Res. Pap. RM-134, 20 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo. 80521.

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